Irradiation of Food in the Russian Republic: A Preliminary Feasibility Study

Agribusiness and Marketing Improvement Strategies Project (AMIS II)

Project No. 936-5457

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Submitted to:

USAID/G/EG/AFS/AEMD
Under DNIX-94-16900-KG11
Contract No. AEP-5457-Q-003061-00

Submitted by:

Abt Associates Inc.
Agribusiness & Marketing Improvement Strategies Project
Project No. 936-5457
USAID/G/EG/AFS/AEMD

TABLE OF CONTENTS

APPENDIX

EXECUTIVE SUMMARY

Background

There is an urgent need to redeploy Russia's nuclear scientists, engineers and technicians from weapons production to more peaceful pursuits. This need led to a proposal to employ these persons in the development of food irradiation in Russia utilizing recovered radioactive isotopes from uranium processing waste.

Objectives

The present study has two objectives. The first is to examine the feasibility of commercial irradiation of foods as a means of reducing the present very high losses due to spoilage and of reducing food-borne diseases in Russia's inefficient food distribution system. We find no major impediments to establishing such a system, but qualify our conclusion in two respects: (1) consumer acceptance of irradiated food in Russia has yet to be established, raising issues of the marketability of such products within Russia, and (2) it may not be feasible or desirable to integrate a food irradiator into a Russian-operated food processing and distribution system as it presently exists.

Our second objective is to advise on the feasibility of establishing a commercial-scale irradiation facility somewhere in Russia in order to demonstrate the benefits of irradiation, and to establish the technical and cost parameters for food irradiation in the Russian Republic. We recommend that this activity move to the next phase -- the preparation of an implementation plan for the demonstration irradiator jointly by AMIS II and NFS/MATEK. Russian nationals associated with the project through NFS/MATEK would be involved in the plan preparation. This report includes a plan of action and estimated costs for the AMIS II portion of the plan preparation.

Technology and Applications

The technology of food irradiation is now well known and appropriate standards have been developed by the FAO, World Health Organization, and the International Atomic Energy Agency. Thirty-five countries have approved food irradiation of more than 30 different foods, and there are some 55 food irradiation facilities in use world-wide (though many are for research purposes), including one commercial-scale plant in the U.S. The foods most commonly irradiated to eliminate the presence of harmful bacteria include poultry, seafood, and meat, while vegetables and fruit are treated to retard ripening and extend shelf life. Grains are irradiated to reduce insect infestation, and spices are irradiated to sterilize them.

Consumer Acceptance and Environmental Issues

The issuance of regulations by the U.S. Food and Drug Administration authorizing irradiation of various foodstuffs reflects the growing acceptance of food irradiation in the world. It also should assure consumers that irradiating food with ^{137}Cesium (Cs) and ^{60}Cobalt (Co) is completely safe. No induced radiation or radiolytic effects have ever been detected from use of these radioactive isotopes. In fact, minor changes in food constituents after irradiation are generally less than for other types of food processing.

In Russia, consumers are apparently unaware that a considerable amount of food irradiation already takes place in their country. Even farm managers from the southern part of Russia disclaim any knowledge of the very large in-line irradiating facility that exists in Odessa to treat grain off-loaded from ocean transport. While mention of irradiation to Euro-Russians and Ukrainians is an unpleasant reminder of the Chernobyl disaster, there appears to be less concern about irradiation as one moves eastward in Russia.

It is unlikely that there will be any environmental issues incident to food irradiation in Russia since the process will be carried out in a self-contained and closely monitored system.

Potential Economic Impact of Food Irradiation

Estimates of food losses due to spoilage in the Russian state-run distribution system range from 30 to 50%, and availability is irregular. A parallel distribution system operated on a much smaller scale by private farmers and merchants delivers better quality food but at much higher prices than the subsidized state system. Thus the Russian consumer faces quality, availability, and price problems. Health problems from contaminated food caused by unsanitary conditions in food processing, shipment and storage probably also occur, although no data on this matter was available for the study.

Integration of food irradiation into the Russian food system, both state-run and private, has the potential to: (1) reduce losses due to insect infestation, (2) extend shelf life of perishable crops by retarding ripening, (3) retard sprouting of root vegetables, (4) control pathogenic bacteria in meat and fish, and (4) sterilize foods such as egg powder to allow extended storage.

Recommendations:

(1) The project should move to the next phase -- the preparation of an implementation plan for a demonstration food irradiation facility to be installed somewhere in Russia.

(2) The selection of products to be irradiated and the location for the irradiator -- key elements in the proposed plan -- should be done if possible with Western food processing companies already operating in Russia because: (a) these environments are most likely to provide the quality control of incoming and finished product which is essential to demonstrating the efficacy of food irradiation, (b) some of these companies sell their products in export markets which readily accept irradiated foods, as well as domestically in Russia, offering the opportunity for the broadest possible market testing of the output from the facility, and (c) processing plants operated by Western companies generally handle high volumes of food on a year-round basis, conditions which are necessary to establish the commercial viability of a food irradiator.

(3) The use of ^{137}Cesium source is recommended for the development of food irradiation in Russia because (a) large quantities of this isotope can be recovered from accumulated nuclear waste, known to be present in Russia, (b) a large number of Russian nuclear technicians can be employed in preparing the isotope in usable form, (c) the low level of radiative emission of ^{137}Cs leads to self-contained

irradiators, requiring a minimum of monitoring, (d) the 30 year half-life of ^{137}Cs requires little recalibration of the irradiator, and (e) the Russians might have an interest in an American designed ^{137}Cs proprietary irradiator now being field tested. The latter unit is being fabricated in the U.S. by the well-known firm of Babcock and Wilcox who also have fabrication facilities in Russia. Accordingly there is some possibility of moving expeditiously if Babcock and Wilcox and the Russians can work out a suitable arrangement.

(4) The implementation plan for a demonstration irradiator should be prepared jointly by the AMIS II Project and Nuclear Fuel Services/MATEK. AMIS II would be responsible for those parts of the plan which relate to <u>applications</u> and <u>specifications</u> for the demonstration facility, while NFS/MATEK would be responsible for those parts which relate to the <u>design</u>, <u>fabrication</u>, <u>installation</u> and <u>operation</u> of the irradiator.

(5) Initial tasks to be undertaken by AMIS II during the plan preparation would include:

- identification of potential U.S. food company participants,
- consumer acceptance surveys in Russia, and
- determination of the general parameters of the irradiator.

(6) Following completion of this work, the AMIS II team would make a presentation of its findings to NFS/MATEK. Decisions would next be made on where and how the irradiator would be built and on its preferred location. Estimates could then be prepared of the cost of fabricating, installing, and operating the unit.

(7) The next phase of the project -- implementation of the plan for a demonstration irradiator -- would be carried out jointly by AMIS II and NFS/MATEK. It will include reaching agreement with one or more food processors (probably including American food companies) and developing technical, cost, and operating specifications for the unit. The final step will be the preparation of a business plan by NFS/MATEK to be used as a basis for attracting the participation of investors from Russia and other countries in the venture which will own and operate the demonstration irradiator.

INTRODUCTION

Under a February 1993 agreement between the governments of the United States and Russia, the U.S. is purchasing 500 metric tons of weapons-grade Highly Enriched Uranium (HEU) to be supplied as reactor fuel-grade Low Enriched Uranium (LEU). Based on the "Project Plows" concept developed in 1991 by Nuclear Fuel Services Inc., it was decided that a joint U.S.- Russian enterprise would be responsible for this downblending, and that the resulting LEU would be purchased by the U.S. Enrichment Corporation (USEC), an enterprise established by the U.S. Department of Energy in 1992. This U.S.- Russian joint venture, chartered in June 1994 as the joint stock company "MATEK", brings together a number of Russian organizations and the U.S. companies Nuclear Fuel Services (NFS) and Allied Signal Incorporated (ASI). The purchase of the downblended uranium is expected to generate about $12 billion in revenue for the Russian government.

The Project Plows concept recognized the importance of providing useful employment for Russian nuclear scientists, for educating Russians in private enterprise, and for improving nuclear safety and environmental controls. While downblending of uranium will initially take place in Russia, MATEK's objective is to progressively downblend in both the U.S. and Russia in order to expedite the conversion of weapons material to a non-weapons form.

In late 1994, Mr. Paul Schutt, President of NFS, proposed that some of the funds generated by the sale of LEU be used to establish a network of food irradiation facilities in Russia (and potentially in other states of the NIS). Not only would this be a useful and productive way to provide additional employment for Russian scientists, but it could potentially contribute substantially to reducing the very high losses in the food distribution system, thus increasing the availability of food to the Russian population. Mr. Schutt proposed to the U.S. Agency for International Development that funds be made available for a study of the feasibility of establishing commercial-scale food irradiation facilities in Russia.

As a first step in that process, the ENI Bureau of USAID requested the AMIS II Project to carry out a preliminary study of the feasibility of commercial food irradiation in Russia. The intention was, if findings were positive, that the study could be used as a basis for obtaining additional funds for carrying out the full-scale feasibility study. Responding to that request, this study was carried out by Richard D. Abbott of Abt Associates, the AMIS II prime contractor, and Dr. Richard S. Gordon of Arizona State University, subcontractor to Abt.

The authors gratefully acknowledge the advice and comments of Mr. Paul Schutt of Nuclear Fuel Services in preparing the study. Mr. John Lightfoot, AMIS II Project Director, provided management oversight for the project. At USAID, we received helpful feedback at various points in the preparation of the report from Messrs. Charles Uphaus and Steve Szadek of ENI/ED/AG, and from Tom Mehen of the Global Bureau.

1. STATE OF THE ART OF FOOD IRRADIATION TECHNOLOGY

1.1 Background

Food irradiation has gained worldwide acceptance. According to an International Atomic Energy Agency (IAEA) report[1], health and safety authorities collectively have approved irradiation of more than 30 different foods in 35 countries. Twenty-one of these countries are actually applying the process, according to the IAEA, including one commercial-scale plant in the U.S. Standards for food irradiation have been developed by the FAO, World Health Organization, and the International Atomic Energy Agency. The foods most commonly irradiated to eliminate harmful bacteria include poultry, seafood, and meat, while vegetables and fruit are treated to retard ripening and extend shelf life. Grains are irradiated to reduce insect infestation, while spices are irradiated to sterilize them.

International interest in irradiation is largely related to mounting concerns over food-borne diseases. Persistently high food losses from infestation, contamination and spoilage, as well as a growing international trade in food products that must meet stiff import standards of quality and quarantine, are areas in which food irradiation has demonstrated practical benefits.

It is well documented that ionizing radiation is differentially absorbed by biological material. Over the last few decades it has been shown that irradiating foodstuffs can reduce or eliminate contamination and/or infestation by undesirable bacteria, fungi, insects, or other living biological material.

Irradiation of food in most industrialized countries is increasing with little organized opposition from consumer groups. Even in the former Soviet Union, it is reported that a large amount of food is "informally" irradiated, in addition to the irradiation of wheat and other grains which is "officially" reported. Sensitivity to public opinion, which has made U.S. food producers and merchants so "gun-shy", appears to be relatively inconsequential in countries such as the Netherlands and France. Thus it appears that the world market place has encouraged this new technology -- the application of nuclear science to food irradiation -- to develop faster elsewhere in the world than it has in the U.S.

1.2 The Technology of Food Irradiation

1.2.1 Radiation Sources

Only gamma rays from ^{60}Cobalt and ^{137}Cesium, X-rays generated by a machine at a maximum energy of five megavolts, or electrons generated by a machine at maximum energy of 10 megavolts, can be used for food irradiation. The reason is that energies from these sources are much too low to induce radioactivity in food (or any material) exposed to them.

IAEA, *Cost-Benefit Aspects of Food Irradiation Processing,* Vienna, 1993

Electron generators, even small units used for research, have so far proved unable to withstand prolonged use and are expensive to operate. ^{60}Cobalt is much more prevalent in the U.S. and Western Europe. However, certain peculiarities of Russian nuclear technology (described below) will favor the use of ^{137}Cesium for food irradiation. While somewhat lower in energy of emission than ^{60}Co, ^{137}Cs has a much longer half life than ^{60}Co, permitting much longer use than ^{60}Co. Irradiators containing ^{60}Co need to be recalibrated on a fairly frequent (monthly) basis because of the continuing decay, and concomitant loss of radiative energy, of this isotope.

1.2.2 Radiation Dosage

Radiation dosage refers to the quantity of radiation energy absorbed by a food as the radiation passes through the food in processing. Radiation dosage is now usually measured by a unit call the gray (Gy) , although the rad was used in the older literature (1 Gy = 100 rads). By 1990, international health and safety authorities had endorsed the safety of irradiation of all foods for dosage levels up to 10,000 Gy (10kGy). This is the amount of radiation energy equal to the heat required to raise the temperature of water 2.4 degrees Centigrade. Virtually all current applications require dosages of less than 10 kGy. It should be noted that radiative sterilization of food generally requires levels of radiation not covered by the 1990 blanket approval. This means that specific country clearance for sterilization is required on a product-by-product basis. In the Netherlands a reasonable clearance process is in place. In other countries, including the U.S., it still appears to be difficult to secure clearance for radiative levels in excess of 10,000 Gy.

All irradiation facilities must be licensed, regulated and inspected by national safety and health authorities, most of whom base their rules upon the agreed-upon international standards and codes of practice jointly established by the IAEA, FAO and WHO. The American Society for Testing and Material (ASTM) has issued dosimetry standards for food irradiation[2]. They are published annually in the *Annual Book of ASTM Standards* along with such amendments as have passed review. The guide "provides the basis for selecting dosimetry systems used to measure absorbed dose in gamma-ray or x-ray fields and in electron beams used for radiation processing of food."

1.3 Worldwide Status of the Food Irradiation Industry

An authoritative summary of food irradiation is contained in a 1990 journal article by Dr. D.W. Thayer of the U.S. Department of Agriculture[3]. Reviewing the use of irradiation on grains, dried spices, vegetables and fruit, fish, poultry and red meats, Dr. Thayer concludes that the evidence supports the safety and efficacy of using ionizing radiation on foods. The full document is included in this report as Appendix A..

ASTM Standard E-1261-88, *Standard Guide for Selection and Application of Dosimetry Systems for Radiation Processing of Food*

D.W. Thayer, *Food Irradiation: Benefits and Concerns*, Journal of Food Quality, #13, (1990), pgs 147-169

Table 1.1, taken from an FAO/IAEA Food Irradiation Newsletter, lists clearances granted for various foods by national authorities, together with permitted dose rates, for Russia, France and the U.S. Russian (then the USSR) approval for irradiation of food was granted largely in the 1960s. The rest of the world began issuing provisional permits in the 1980s. In 1987, four countries - Canada, China, Cuba and France - each installed at least one demonstration or commercial food irradiation facility. Commercial operating authority was firmly established by the end of the decade, particularly after the U.S. cleared irradiated food in 1987. As seen in the table, irradiation of spice and similar dried food specialties has been approved for a decade or more for use in Europe and the U.S. It was reported to us by users that, no matter where grown, the vast majority of such products are irradiated in France before further distribution.

While reports vary, there appears to be a consensus that, by 1993, about 55 food irradiation facilities were operating around the world. In the U.S. there are a number of laboratory or small scale irradiation facilities but, to our knowledge, as of 1995 the Food Tech facility in Florida is the only one in the U.S. capable of handling truckload quantities of produce, meat or poultry. This facility was privately constructed by a group of citrus growers in the Orlando-Tampa area. Currently it is being used to demonstrate efficacy and irradiation economics for a variety of meat, poultry, fruit and vegetable products instead of being dedicated solely to citrus or any other one use.

Through the present (1995), the US radiation processing industry is largely involved with sterilization of medical supplies and equipment. Much of the radiation processing equipment and facilities in the U.S. are designed and manufactured by one Canadian company, Nordion Company. This same company, under license from the Canadian Nuclear Authorities, also manufactures ^{60}Cobalt from ^{59}Cobalt. Nordion supplies about 90% of the North American market for ^{60}Cobalt.

Two recent events accelerating U.S. industry adoption and consumer acceptance of food irradiation are 1) outbreaks of *Salmonella* and *E-coli* contamination of poultry and slightly-undercooked meat and, 2) the imminent banning of methyl bromide as a crop fumigant.

In general, there appears to be a consensus in the food industry that, by the end of the century, irradiation of ”main dish” items in the U.S. will be commonplace. On the other hand, levels of irradiation permitted in the U.S. also reflect a complex and sophisticated food distribution infrastructure which safeguards food quality from producer to consumer. Such a system does not exist in Russia. An important issue, explored later in this report, is whether it may be necessary to use higher levels of irradiation in Russia due to the higher potential levels of food contamination.

Table 1.1

Irradiation Clearances Issued by Authorities in Russia, France, and the U.S.

(as of August 1991)

Product	Purpose	Dose Permitted (kGy)	Approval Date
Russia			
Potatoes	Sprout Inhibition	0.3	1973
Grains	Insect Disinfestation	0.3	1959
Dried fruits	Insect disinfestation	1.0	1966
Dried food concentrates	Insect disinfestation	1.0	1966
Onions	Sprout inhibition	0.06	1973
Beef/pork(semi-prepared)	Shelf-life extension*	6.0-8.0	1964
Prepared meat products	Shelf-life extension*	8.0	1967
Poultry(eviscerated)	Shelf-life extension*	6.0	1966
France			
Potatoes, onions, garlic	Sprout inhibition**	0.075-0.15	1972
Spices, aromatics	Decontamination	11.0	1983
Gum arabic	Decontamination	9.0	1985
Dehydrated vegetables	Decontamination	10.0	1985
Poultry meat (de-boned)	Decontamination	5.0	1985
Dried fruit & vegetables	Insect disinfestation	1.0	1988
Strawberries	Shelf-life extension	3.0	1988
United States			
Wheat and wheat flour	Insect disinfestation	0.2-0.5	1963
White potatoes	Shelf-life extension	0.05-0.15	1965
Spices, dry seasonings	Decontamination/Insect disinfestation	30	1983
Dry or dehydrated enzymes	Control of insects	10	1985
Pork carcasses	Control of *Trichinella*	0.3-1.0	1985
Fresh fruit	Delay of maturation	1.0	1986
Poultry	Decontamination	3.0	1990

*   Experimental batches only
** Provisional approval

Source: FAO/IAEA, *Supplement to Food Irradiation Newsletter*, Vol. 15, No. 2, Oct. 1991.

1.4 International Practices and Standards for Food Irradiation

Impetus for approvals of food irradiation by various national health and safety authorities came from the 1983 adoption of a worldwide irradiation standard by the *Codex Alimentarius Commission*, a joint body of the Food and Agricultural Organization (FAO) and World Health Organization (WHO), representing 130 countries, which sets and coordinates global food standards.

The IAEA regularly disseminates relevant information concerning food irradiation. Its publications include lists of countries that are using or plan to use food irradiation technology. It has issued a number of bulletins which describe how the technology works. The agency convenes meetings and publishes reports on proceedings, and it summarizes reports on results of international scientific research and testing and recent market trials of irradiated food. It also reviews relevant aspects of international trade. With respect to food safety, this area is one which the IAEA operates joint programs with the FAO. It is one of many fields in which the IAEA assists countries in their efforts to apply nuclear technologies for social and economic development.

The U.S. has developed its own irradiation practices and standards. However, there are significant differences between the nuclear situation in Russia and the U.S. In the case of the project discussed in this report, it is felt that it would be a mistake to insist on U.S. practice or standards for Russia, provided, of course, that the desired effects are obtained in a safe and acceptable way, with no increase in hazard to the Russian plant worker or consumer. Although the technology is known in the U.S., there has been no plant-scale operating experience in the U.S. which might be applicable in Russia, such as the use of ^{137}Cesium instead of ^{60}Cobalt in commercial irradiators.

However, there are some innovative American technologies not now being used in the U.S. which might be usefully applied immediately in Russia. As long as such technologies meet international safety standards, it will be important not to superimpose the prolix U.S. approval and licensing process on any proposed operation. Unfortunately, the conservative U.S. regulatory process often appears to foreign observers to be designed mainly to insure that the U.S. nuclear industry and regulators are "blame-free”. On the other hand, the Russian project, should it go forward, must ensure acceptance of appropriate safety and regulatory measures in a way which will not unduly burden the creation of a useful industry.

1.5 Effects of Irradiation on Food

Food scientists have studied the effect of irradiating foods over many decades. Process benefits are well identified, as well as limitations. Most foods, including fruits, vegetables, seafood, meats, and grains, are suitable for radiation processing. However some, such as dairy products, are not. To date there is "<u>no substantiated evidence</u> to confirm fears that irradiated foods are harmful to eat or that they will cause adverse health effects over time".

A joint WHO - FAO publication[4] summarized the results of major studies on the effects of irradiation on food. The main points are summarized below.

Chemical compounds. At low dosages it is difficult to detect chemical change in irradiated food. At higher dosage levels, such as required for meat, many chemical changes can occur; some sugars, vitamins and other nutrients are lost or chemically altered. Since similar losses or alterations occur in other foods that have been processed by other techniques these changes are not considered unusual or dangerous.

Microbiological changes. Graded dosages of radiation produce graded responses in microbial organisms starting with growth retardation at low dosages, then injury and, at higher dosages, death, meaning the food is effectively sterilized. Radiation sterilized food products can be sealed and safely stored at room temperature in the same way that conventional canned foods may be stored. Extensive research has not been able to produce any evidence that irradiation of microorganisms produce mutant strains that "warrant concern". Microbial survivors of irradiation are injured enough so as to be more susceptible to heat or cold killing. This explains why, on a case by case basis, radiation levels in excess of 10 kGy to achieve sterilization has been approved, mostly in Western European countries.

Other changes. The taste and smell of most foods are not noticeably affected. Dairy products are the exception; virtually all irradiated milk products develop off-flavors or undesirable smells, even at low dosages of radiation. On the other hand, there are no documented changes in nutritional quality in foods that would not be expected from any oxidative process (in this case, activated electrons) introduced into oxidation-prone media containing certain fat-soluble vitamins, pigments, unsaturated fats, etc. Ordinarily such losses are easy to measure and easily compensated for.

WHO/FAO, *Food Irradiation: A Technique for Preserving and Improving the Safety of Food"*, 1992.

2. CONSUMER ACCEPTANCE OF IRRADIATED FOOD

2.1 Background

As discussed in other parts of this report, the benefits of food irradiation may be summarized under two headings: **economic** (reduced losses due to spoilage), and **public health** (removal of disease-causing pathogens in food, replacement of banned fumigants in killing various plant pathogens). These undoubted benefits tend not to be understood by a public generally ill-informed about irradiation and frightened by unfounded claims of health hazards by vociferous advocacy groups, especially in the United States.

The main purpose of this chapter is to review worldwide experience with consumer acceptance of food irradiation, especially for lessons which might be relevant to Russia. Since more work on this subject has been done in the United States than in any other country, and because government policies and consumer attitudes in other countries tend to be influenced by what happens here, the chapter begins with a review of relevant U.S.studies and experience. The following section looks at experience worldwide. For the states of the former Soviet Union, we are not aware of any relevant studies, and available resources did not permit any kind of rigorous survey to be carried out there. As a preliminary indication of consumer acceptance among a specialized group, we carried out a focus group discussion among a group of Russian and Ukrainian scholars in residence at Arizona State University. Results are in Section 2.4.

2.2 Consumer Acceptance in the United States

Numerous polls, surveys, and focus group discussions of consumer acceptance of food irradiation have been conducted in the United States since 1984. Despite scientific evidence of the safety of irradiated food, consumer exposure to irradiated foods in the U.S. during the last decade has been quite limited -- due in part to cost considerations but also to the opposing viewpoints of various advocacy groups appearing in the press. This limited experience possibly accounts for the fact that surveys often produce conflicting results. For example, one nationwide survey in 1989 found that 60% of those surveyed had heard of irradiation, whereas a 1990 survey reported only a 25% awareness. A 1989 nationwide survey showed that 44.5% of respondents were likely or very likely to purchase irradiated products, while surveys in 1984 and 1986 on acceptance of irradiated fish products found that two-thirds were willing to purchase them. Some studies found that half the consumers surveyed want more information before they are willing to purchase, while others showed that only about 25% thought they had too little information.

Within the last few years, more irradiated food products are appearing in stores and consumers are becoming more aware of them. Consumer views on food irradiation now tend to be expressed within the context of food safety in general. Consumers express an equal or greater concern about the safety of food additives, pesticide residues, growth hormone residues, and antibiotic resistant bacteria as they do about irradiation.[5] Reinforcing that trend is heightened interest in finding alternative methods of reducing food-

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"Social Demographic and Attitudinal Determinants of Consumer Acceptance of Food Irradiation", Sapp, Harrod and Zhao, in Agribusiness. Vol. 11, No. 2 (1995), page 118.

borne pathogens in meat, poultry and fish due to recent cases of illness and death caused by contamination of these foods. The impending ban on the use of methyl bromide as a fumigant for grain, fresh fruit and vegetables has likewise increased interest in the use of irradiation as an alternative.

Experience with the marketing of irradiated chicken in the U.S., beginning in 1992, provides an instructive case study in consumer acceptance. Poultry is of particular interest due to recent incidents of poisonings from *salmonella*- tainted chicken.

In 1992, following FDA approval of irradiated poultry and publication of regulations on the process by the USDA, a Florida-based company began commercial-scale production of irradiated poultry. The plant operator, Food Technology Services of Mulberry, Florida, now markets irradiated chicken under the *Nation's Pride* label to a fresh foods supermarket in suburban Chicago and an institutional food distributor in Florida which sells to hospitals and long-term care facilities. The supermarket, Carrot Top, has had excellent results with consumer acceptance of the product, following successful marketing by the store of irradiated strawberries. The company began by running articles on irradiated poultry in a customer newsletter stressing the benefits of eradicating harmful bacteria. Extended shelf-life of the product was considered a side benefit. Consumer acceptance was excellent; sales of poultry have increased 75% since the irradiated product was added, and the store has stopped carrying unirradiated poultry.

This "fresh food" type of store can be expected to have a rather special, health conscious and well-informed clientele. Thus, publication of factual information on irradiation through the store's newsletter had a positive impact on consumer attitudes.

2.3 Consumer Attitudes and Experience with Food Irradiation Worldwide

The use of food irradiation as a method of processing and preserving food is more widely accepted in other countries than in the United States. By 1988, health authorities in 35 countries had approved irradiation of more than 30 foods, including grains, spices, fruits and vegetables. Twenty-one of these countries were actually applying the process and eight others had plans to do so.[6] The very high food losses experienced in developing countries provided a strong impetus for the introduction of the irradiation process, and led to joint efforts of the FAO, IAEA, and WHO to promote its use in these countries.

Consumer views on food irradiation are expressed within the context of food safety in general. There is an equal or greater concern about the safety of food additives, pesticide residues, growth hormone residues, and antibiotic resistant bacteria.[7]

The World Health Organization has been at the center of public debate on food irradiation for many years. In 1980, an Expert Committee on the Wholesomeness of Irradiated Food found that "food

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International Atomic Energy Agency, IAEA News Features, Vienna, Dec. 1988.

Sapp, Harrod and Zhao, page 118.

irradiated up to an overall absorbed dose of 10 kiloGray (kGy) presents no toxicological hazard and introduces no special nutritional or microbiological problems".[8] In 1983, the Codex General Standard for Irradiation of Foods was adopted by the Codex Alimentarius Commission. In 1992, an expert panel reviewed over 200 studies and concluded that when carried out under existing Good Manufacturing Practices, "the process of irradiation will not introduce changes in the composition of food which can produce, from a toxicological point of view, an adverse effect on human health."[9] The WHO press release quoted here went on to note that public acceptance of food irradiation is identical to that which took place at the turn of the century with respect to pasteurization, now taken for granted by everyone.

2.4 Food Irradiation Facilities in Use

An important indicator of public acceptance of irradiated food outside the United States is the number of existing irradiation facilities already approved and operating. As of 1988, 26 full-scale or pilot-scale commercial facilities were operating in eighteen countries (including the U.S.) and an additional 30 units were under construction or being planned.[10] As noted above, by 1993 there were a reported 55 facilities operating worldwide, including the U.S.[11]

Spices and dehydrated vegetables are irradiated to remove insect contamination in many countries, including Argentina, Belgium, Brazil, Canada, Chile, Denmark, Finland, France, Germany, Hungary, Israel, Korea, Netherlands, Norway, South Africa, the U.S., and Yugoslavia.

Large tonnages of grain are irradiated at the port of Odessa, in Russia, to eliminate insect infestation in imported products. While there are officially no other approved irradiators in Russia, unofficially some 30 units are said to be operating on a variety of foods. A similar situation exists in Ukraine. As far as we can learn, among former East Bloc countries, only in East Germany are consumers fully aware and accepting of irradiated foods.

Potatoes and onions are irradiated to retard sprouting in Chile, Cuba, China, Germany, Japan, South Africa and Thailand. Apples are also irradiated in China.

France, Belgium and the Netherlands are the most active in irradiation of poultry and seafood to eliminate pathogens. Electron-beam irradiation of blocks of mechanically de-boned frozen poultry is carried out in France. Frozen seafood is irradiated in Belgium and the Netherlands. As described in the

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WHO Press Release #35, 27 May 1992

Ibid, pg.1

Food Irradiation Newsletter, Vol. 10, No. 2, November 1986

Marcotte, Michelle, *Commercial Food Irradiation, Market Tests and Consumer Attitude Research*, Prepared for the UN Environment Programme, February 1994 previous section of this chapter, irradiated poultry is also being marketed in the United States. Chile has also produced irradiated poultry products on a small scale.

France has done the most work with other products, irradiating quantities in excess of 100 tons annually of casein, gum arabic, dried fruit, frog's legs, shrimp, as well as smaller quantities of almonds, pistachios, and hazel nuts.

Other products which have been produced in small quantities and test marketed in various countries include: oranges, grapefruit, pears, bean sauce, garlic, strawberries, mangoes, and papayas. Whether or not these products, or any of the others listed above, will actually be irradiated depends on volume available, as well as on reduction or the magnitude of elimination of waste, infection, infestation, etc. There has to be a volume divisor because of the fixed/sunk cost of the irradiator itself.

2.5 Informal Group Surveys of Russian and Ukrainians in the U.S.

Informal focus group discussions were conducted at Arizona State University with visitors from Ukraine and Russia. It was interesting to note that a visiting group of 13 Ukrainian farmers and agribusiness managers (Cochran Fellows), denied awareness of any significant amount of food irradiation taking place in the Ukraine. Of course, this is contradicted by all available intelligence. It does indicate that former Soviet Republics governments revealed very little, if anything, to the general public about the extent of food irradiation taking place anywhere in their countries. Because published information is at least two or more years behind, it is only now becoming clear that food irradiation is increasingly becoming an accepted procedure in the former Soviet Union.

The Ukrainian group acknowledged that there were considerable losses in their harvesting, packaging and storage of food. However, even before "irradiation" was directly suggested as a possible beneficial process, murmurs of "Chernobyl" were coupled to comments concerning contamination of food. When the topic of possibly upgrading food production, processing and distribution employing irradiation as an added feature was mentioned, the Ukrainians were uniformly negative. They felt that to introduce irradiated food into Russia (or the Ukraine) would require much greater consumer acceptance and education than currently exists.

Discussions with a group of Russian visitors, on the other hand, revealed a greater consciousness of the deterioration in food quality since the demise of the Soviet Union. They were much less emotional about irradiated food, but did feel that considerable consumer education regarding the value and safety of irradiated food would be required before irradiated food could be successfully introduced into the Russian Republic.

2.6 Conclusions

< Consumers generally lack information on the benefits and safety of food irradiation.

< People are becoming more concerned about health risks from food, such as pesticide residues in

fresh fruit and vegetables and food-borne pathogens in meat and poultry.

< Many recognize the benefits of using irradiation as a safe alternative to the use of chemicals and fumigants in food, and as a way to reduce illness caused by contaminated food.

< The public wants irradiated foods to be labeled as such.

< In the absence of generalized knowledge of food irradiation, consumers rely on the media for information. The negative views of consumer advocacy groups tend to carry more weight than do factual accounts by government and industry.

< There is a need for better communication by public agencies of the benefits and safety of food irradiation.

< Routine use of irradiation will depend on the magnitude of the cost savings to the trade, but long term consumer acceptance is more likely to depend on perceived health benefits.

3. POTENTIAL ECONOMIC IMPACT OF FOOD IRRADIATION IN RUSSIA

3.1 Overview of the Russian Food Distribution System

The Russian food distribution system is currently a hybrid of a state run system operating in a partially liberalized environment. The state system continues to direct large scale food production, transportation, storage, processing, and distribution, and delivers large volumes of food to urban centers by rail, barge, or truck, for distribution through state run stores and cooperatives. In parallel with the state system, an increasingly vibrant private sector distribution system is now operating, supplying consumers with goods of higher quality -- and higher prices -- than do state channels.

3.2 Food Distribution Channels in Russia

Figure 3.1 on the following page depicts graphically the various channels through which domestically produced food moves in Russia and other states of the former Soviet Union.[12] Most of the food produced on a large-scale on state and collective farms moves to market through state channels. State and collective farms now have the right to negotiate with urban distribution entities for delivery of commodities, though a portion of their production must still be delivered at prices fixed by the state. A separate network of consumer cooperative stores obtains supplies from collective farms and private farmers. The large farms also barter some of their output with industrial enterprises against shipments of capital goods, or consumer goods for their members and employees. Some industrial enterprises have established auxiliary farms of their own to supply their employee canteens and to supplement food available to employees through market channels.

Most of the food items which reach consumers through private channels come from part-time farmers who have been allotted plots of land on state and collective farms, and from full-time private farmers who have succeeded in obtaining large acreages on collective farms which have started to redistribute land to members. Much of this privately-produced food is sold directly to consumers at farmers' markets, a system that has long existed in the former Soviet Union, though on a smaller scale than at present. More recently, an increasing amount of this food is moving to privately operated shops in urban areas (not indicated on the chart). Privatized state food stores are also now permitted to purchase food directly from producers or wholesalers and sell it alongside food supplied through state channels.

The Russian consumer faces quality, availability, price and health problems with respect to the food available in stores.

The chart does not take into account increasing imports of fresh fruit and vegetables from the Netherlands, Spain and Greece.

! ***Quality:*** State retail stores often offer damaged or unfresh fruit and vegetables. Despite this, Russian consumers prefer fresh foods because available bottled juices, canned soups, and packaged foods are considered to be of questionable quality.

Figure 3.1

- ***Availability:*** Russian consumers complain of inconsistent availability of vegetables. . With economic instability, food has become a barter item for producers, further contributing to food shortages in stores.
- ***High Prices:*** Prices of quality meats and some vegetables available through private channels are beyond the reach of most consumers.
- ***Health:*** While we have no documentation on health problems from tainted food in Russia, such as those caused in meat and poultry by *salmonella* or *E-coli,* the problem undoubtedly exists, as it does in every country. It may be surmised that the problem is more serious in Russia than elsewhere, given the poor state of the Russian food system and the lack of attention to sanitary standards in food handling.

Per capita consumption of food items in Russia in 1992 and 1993 is shown in Figure 3.2. While the accuracy of some of the data is suspect, it does serve to indicate the importance of potatoes and vegetables in the Russian diet. Russian per capita consumption of potatoes, for example, is roughly 120 kg per year (265 lbs.), compared to an average of 64 kg in Western Europe.

3.3 Losses in the Food Distribution System

According to an OECD estimate[13], 30% to 40% of total agricultural production in Russia is lost in transport and storage from harvest to the consumer's plate. Data from this study on losses on products which might be targeted for irradiation -- are shown in Table 3.1.

Members of the Russian group of visitors to ASU who are private farmers or farm managers stated that quality-conscious consumers are already sourcing foodstuffs directly from them. They claim to have very low levels of food loss due to spoilage, a claim substantiated by other observers in Russia. It is generally recognized that the continuing problem is in the larger state-owned properties, warehouses and consumer outlets, as well as the nationwide distribution system

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OECD. <u>The Soviet Agro-Food System and Agricultural Trade: Prospects for Reform,</u> Paris 1991

Figure 3.2

Table 3.1

Product	***Quantity Lost***	***Causes and Sources***

Meat and Meat Products	2-3 million	Includes losses in retail trade and animals which perish or are

Sugar Beet and Sugar	over 1 million	Caused mainly by harvesting too early; shortage of transport

Potatoes	30%-50% of	Low degree of mechanization in harvesting, shortage of labor,

Vegetables	30%-40% of	Lack of labor and transport from the fields.

Fruits and Berries	40% of	20% (half the total) loss estimated to occur due to improper

3.4 Causes of Inefficiencies in the State Food Distribution System

Inefficiencies exist throughout the Russian food distribution system, as detailed below.

! ***Storage:*** Lack of proper storage technology, discipline, standards and equipment leads to losses, both on the farm and at urban distribution centers. Limited on-farm storage capacity for potatoes, for example, means that the bulk of the crop must be transported to urban storages during and immediately after the harvest. Because of rough handling in transit, damaged potatoes arrive at urban distribution warehouses, many of which are not equipped with proper refrigeration.

! ***Transportation:*** Transportation is a weak link in the Russian food distribution system because of the unsatisfactory quantity and quality of available trucks and a limited highway network. The poor state of roads in many rural areas adds to transportation costs due to time delays and damage to vehicles. Shortage of refrigerated trucks and rail cars contributes greatly to food loss and inefficiencies since large volumes of produce are transported in open, unrefrigerated vehicles. Often, trucks do not carry full loads on both outbound and return trips, contributing to distribution inefficiency.

! ***Wholesale Structure:*** The lack of integration among wholesaling functions such as storage, transportation, and retail delivery lead to gross inefficiencies in the system. Wholesale distribution facilities supplying the cities must rely on uncertain deliveries and variable quality of goods shipped from widely scattered state and collective farms, who are themselves relying on an inefficient transportation system. In the case of fruit and vegetables the resultant multiple handling leads to further damage.

! ***Sales, Marketing, and Management:*** Sales, marketing, and management skills are weak in Russia. Analysis of a group of Russian vegetable wholesalers indicates that there is a lack of responsiveness to customer needs and little attempt to seek new customers. There is little use of advertising or research on competitors. Introduction of new products and services is also minimal.

3.5 Integration of Food Irradiation into the Russian Food System

Food irradiation has been endorsed by international authorities because of its capacity to help address “serious problems of food supply, health and nutrition, and global trade and economics" (IAEA #5). These benefits can be realized in Russia through:

, decontamination and disinfestation, reducing losses due to insects,

, extension of shelf life, thereby reducing spoilage during transportation and storage,

, control of pathogenic bacteria and other organisms, with attendant health benefits, and

, actual sterilization of food products such as egg powder where the Russian producing source is likely to be infected and where the produce is not canned nor refrigerated and likely to be stored for long periods of time.

Irradiation processing enables food to be stored longer and to meet stringent tests of quality and safety when integrated within an established system for the safe handling and distribution of food. However, it is well known that irradiation alone, as a preservation technique, will not solve the problem of post-harvest food losses. Inefficient and unsanitary processing operations, time delays in handling, transportation weaknesses, and poor marketing practices are all areas outside of food storage that contribute to Russia's food losses. Even if a food is safely processed, there is no assurance that its quality and wholesomeness will be preserved as it passes along the food chain to reach the consumer. <u>Radiation processing can only cut food losses if good quality products are delivered to the irradiator, and the product is properly packaged, stored, and shipped after irradiation.</u>

If food irradiation is to be cost effective in Russia, therefore, the integration of food irradiators into food processing lines will require the imposition of higher quality standards from the incoming raw materials all the way through to the final packaged product and its distribution to the consumer. In this way, food irradiation has the potential to become a catalyst for the upgrading and modernization of the Russian food system and the reduction of the high loss rates currently experienced. The demonstration facility itself could serve as a model for food processing plants in the future.

4. FEASIBILITY OF A DEMONSTRATION IRRADIATION FACILITY

4.1 Introduction

The objective of this study was to examine in a preliminary way the feasibility of commercial irradiation of foods in Russia. Based on our findings in the preceding sections, we find no major impediments to establishing such a system, but qualify our conclusion in two respects: (1) consumer acceptance of irradiated food in Russia has yet to be established, raising issues of the marketability of such products within Russia, and (2) it does not appear feasible or desirable to integrate a food irradiator into a Russian-operated food processing and distribution system as it presently exists.

A second objective was to advise on the feasibility of establishing a commercial-scale irradiation facility somewhere in Russia in order to demonstrate the benefits of irradiation, and to establish the technical and cost parameters for large-scale food irradiation in the Russian Republic. In this section of the report, we examine a number of factors bearing on establishing such a demonstration irradiator in Russia and recommend that an implementation plan be prepared for the facility. Finally, a draft work plan is presented outlining actions which would be taken by an AMIS II team working in cooperation with NIS/MATEK to complete the plan.

4.2 Potential Irradiation Applications in Russia

Factors which enter into the selection of possible applications for a demonstration irradiator in Russia include: (1) consumer acceptance of irradiated food in Russia, (2) identifying an application or applications with sufficient product throughput to economically justify the cost of the facility, (3) potential supplementary non-food irradiation applications to provide additional justification for the facility, and (4) the feasibility of involving U.S. food processors with operations in Russia to export high quality packaged irradiated foods to other countries.

4.2.1 Marketability of Irradiated Foods

Our preliminary conclusions from discussions with Russian and Ukrainian visitors to Arizona State University is that acceptance of irradiated food (if labeled as such) increases with the distance consumers are located relative to Chernobyl. For example, it may be that acceptability is not a problem in the Russian Far East (or in the Asian republics of the former Soviet Union). During the next phase of the project, we propose to conduct surveys in various parts of the country to more firmly establish the degree of marketability of irradiated food in Russia and the NIS.

As discussed below, there a number of good reasons to initially focus on export markets for the irradiated foods in countries that readily accept irradiated foods, such as South Africa, France, and China. Nevertheless, if the demonstration irradiator is to provide useful information on the Russian market for irradiated food, some portion of the output should be marketed locally. The task of the next phase is to determine what mix of local and export markets is desirable and achievable.

4.2.2 Product Throughput Volumes

Most commercial irradiators in service today around the world are large," general purpose" facilities, capable of irradiating almost any food product. In order to operate economically, they must process considerable volume, two to three shifts a day, almost every day of the year. This means that such large irradiators will generally have to have product shipped to them which they transship to another site, post-irradiation. For many applications, such as the radiosterilization of high value spices, such cost is not a serious economic deterrent because added shipping charges do not appreciably affect products with high unit values. However, the cost of low-dose irradiation of lower value foods can be formidable, particularly if transportation expense is already a significant item of cost.

Experience at the FOOD TECH ^{60}Cobalt irradiation facility in Florida is instructive. The plant processes a wide variety of locally-produced food, as well as non-food items. Trucks arrive with product in totes or on pallets which are put through an automated irradiation process line and immediately shipped out again. In Russia, the odds of finding any agricultural area equivalent to Florida are remote. If a Russian plant is to depend on fruit and vegetables alone, that would mean availability of product during a relatively short growing and harvesting periods, with resultant high unit costs. The addition of potatoes could improve this situation, since with proper scheduling and storage the potato processing season can be significantly lengthened. If multi-ton quantities can be delivered for half a year, costs of $0.10-$.25/lb may be attainable.

These issues will be examined by the AMIS II team in the second phase. However, it is likely that if break-even on a cash flow basis is to be approached, the first commercial plant will either have to concentrate on irradiating year-round production of meat, poultry and fish for domestic or export markets, <u>or</u> secure agreement from all concerned that the plant will be significantly subsidized for some period of time.

4.2.3 Alternative Non-Food Items for Irradiation

As noted above the FOOD TECH plant in Florida is currently sterilizing a variety of non-food items, such as food packages and containers. One example is small plastic coffee creamer cups used in restaurants. Another application used widely is the sterilization of medical supplies such as bandages and personal items such as condoms and tampons. A similar approach might be used by the first Russian commercial demonstration irradiator. Besides use as an in-line irradiator in a food plant, it will almost certainly have the capacity to sterilize an entire range of biomedical products. The next phase of the project will examine the demand for biomedical sterilization by both Russian organizations and U.S. companies who may be going to establish operations in Russia.

4.2.4 Potential Participation of U.S. Food Companies

Fortunately for this venture, several major U.S. processing companies have located operations in Russia to process meat, poultry and fish, as well as fruit and vegetables. Most companies are willing to explore use of in-line irradiation as part of their effort. They all intend to upgrade production, processing, storage and eventual distribution to markets in Russia and the NIS or elsewhere. Several companies have indicated an interest in exploring the use of irradiation further, provided that they do not have to do the pioneer work to get market acceptance of an irradiated product. As we understand the matter, only in France, Holland, South Africa and the Peoples Republic of China is irradiated food accepted if it meets international standards. We have also been told that the Asian Republics of the NIS readily accept irradiated foods, but this information would need to be confirmed.

The companies with whom conversations have been held all wish formal descriptions of what the project might entail. They are not averse to participating but they want to know what their financial and market risk would be. The companies working in Russia with the Citizens Network for Foreign Affairs[14] are particularly receptive. However, as with the others, they are too busy starting up their processing operations to think about the special problem of marketing irradiated food. The companies with the most current interest, and their products, are:

- Continental Grain (poultry & eggs),
- ConAgra (potatoes, exploring fresh market and companion storage systems),
- Magna C (fisheries in the Russian Far East), and
- Ventures East (meat and dairy).

Other companies with whom we have talked include:

- Ralston Purina (canned & frozen food),
- Ferruzzi (pastas, processed grain), and
- Several divisions of RJR.

Discussions have also started with companies interested in fast-food operations. They are less cost sensitive, require high quality at their outlets and need to find ways to overcome problems in the Russian food processing and distribution system. On the other hand, their level of usage will be very small for a while.

Any agreement with a cooperating food processor should specify the use of “down time” for irradiation of food products for test marketing and/or radiosterilization of biomedical products and waste. This should be feasible **if** a cooperating food processor can be identified who accepts operation of the unit in this manner when its processing line is down.

4.2.5 Potential Marketability of First Irrradiated Products

Under the Food Systems Restructuring Program funded by USAID.

While long term one has to consider the willingness of the Russian consumer to accept irradiated food, for the purposes of the demonstration markets of sufficient magnitude that are immediately available need to be selected. Only in this way can cost/benefit ratios be established adequately for the Russian ^{137}Cs irradiator. Some examples of such products uncovered by our early contacts are:

- *Dried egg powder:* A major U.S. company has a contract to produce about 20,000 tons annually for use by the Russian military. The final product should be essentially sterile.
- *Fresh and frozen fish:* Several important markets in the Pacific Rim will accept irradiated product. Specific arrangements have to be defined, and product clearance and quality control measures -- all related to customer country regulations and specifications -- have to be developed.
- *Meat and poultry for a "nuclear establishment city":* The Russian nuclear program is/was based on several rather large cities of two to three million people each of which are treated as restricted enclaves. It is believed that inhabitants of these cities would accept irradiated food without question.
- *Bio-medical material:* Russian medical administrators and firms will be interviewed to learn what institutions have bio-medical waste to be sterilized, or need to dry sterilize goods such as containers, syringes, bandages, and whether they have the funds to pay for such sterilization. U.S. medical supply firms potentially locating in Russia will also be interviewed.

4.3 Selection of an Irradiation Source

Worldwide, two processes are utilized for industrial irradiation: gamma radiation from radioisotopes and electrons from accelerators. This report recommends that the commercial demonstration team establishing a prototype food irradiation system in Russia consider employing radiation from radioisotopes only. There are two main reasons for this:

(1) Electrons are much less penetrating than gamma rays (less than an inch for most foods). Electron usage is generally limited to items with a relatively low density. Further, at least in U.S. experience, electron generators are both expensive and troublesome to operate on a sustained basis because of the extremely high voltages required (millions of electron volts) and the very high vacuum systems required.

(2) It is well known that radiation from the radioactive isotopes of Cobalt and Cesium does not induce radioactivity nor induce toxic, mutagenic or carcinogenic radiolytic products in food. Further, irradiative processes employing either isotope have been shown to disinfect grain and flour, inhibit sprouting in tubers and bulbs, alter (positively) postharvest ripening and senescence of fruits, inactivate and eliminate bacterial pathogens in meats, poultry, fish and shellfish. While ^{60}Cobalt is routinely manufactured in Russia, this report recommends that the team begin operations using ^{137}Cesium for these reasons:

  - ^{137}Cesium is produced when reactor fuel is reprocessed. Virtually every country in the world reprocesses its reactor fuel <u>except</u> the U.S., which may explain why usage of this isotope has not advanced in this country. Because isolation and preparation of isotope is quite labor intensive, preparation of ^{137}Cs for food irradiation would provide additional economic incentive for the Russian nuclear industry, something that is clearly important at this juncture in Russia's transformation. Standard uranium reprocessing will generate more than adequate supplies of ^{137}Cesium which can be sold or purchased for irradiative use.

, Because ^{137}Cesium has lower energy than ^{60}Cobalt, a Cesium irradiation facility does not need the same amount of shielding and other protective construction ^{60}Cobalt requires. This means that in-line radiation processing can be built at lower cost to process smaller volumes than would be economic for ^{60}Cobalt usage. Further, ^{137}Cesium's 30-year half life eliminates the need for monthly recalibration of radiation dosage, required by ^{60}Co's relatively short half life of 5.26 years.

, ^{137}Cs along with ^{60}Co is approved for food irradiation use by all countries that permit introduction of irradiated food into the food supply. The safety of food irradiated with ^{137}Cs is well known and adequately documented.

4.4 Irradiator Design Considerations

We conclude that there is a need for a small self-contained and simple irradiator which:

! must be inherently safe with regard to radiation exposure to plant operators,
! must be prefabricated and designed for ease of use by buyers,
! can be used “in line”,
! must be economically competitive,
! requires a minimum of training to use, and
! can be easily reconfigured/combined as needed.

One such system is under development in America and should be thoroughly investigated: it utilizes ^{137}Cesium, and is designed to process a standard 48' X 40' pallet or bin of material. The designer claims the "system is so simple that it will accommodate any materials handling system without specially designed expensive conveyor systems. In effect it can use whatever is available... from a forklift truck to hand loading..."

The first commercial model of this Gray*Star Cesium irradiator should be completed by the end of 1996. It is slated for delivery to Dr. D.W. Thayer of the Eastern Regional Center, USDA, for beta-site evaluation. Dr. Thayer plans an extensive series of experiments and tests to confirm prior calculations of efficacy. Martin Stein, the inventor and President of Gray*Star, informed us that, thereafter, the company will complete an irradiator every four months or so. Stein already has commitments for two or three irradiators and advised that to assure delivery buyers have to “get in line” by paying a modest deposit ($10,000). The deposit is supposedly returnable until the moment fabrication is started. This is a sensible suggestion, but it also establishes a tentative time line for actually installing this type of irradiator in Russia: probably late 1997.

The question to be explored with this system is whether its developer would license the system for construction in Russia, playing some role in supervising manufacture and use. What is interesting is that he has concluded an arrangement with Babcock & Wilcox to fabricate his unit. Babcock & Wilcox currently operate joint ventures in Russia. However, the question must be asked: will the Russians want to develop their own system because they consider an American design would be too expensive or not suitable for their cost-basis?

Therefore, assuming that the prototype irradiator performs as specified in the hands of Dr. Thayer of the USDA[15], it will be important to ascertain if this American technology/Babcock & Wilcox connection could speed up the installation of the first irradiator. Based on what is known about Russia, the odds are that the costs reflected below for irradiation with ^{137}Ce should be significantly less in Russia than in the U.S. Adoption and modification of the Gray*Star system then could speed up the employment of Russian nuclear scientists in reprocessing fuel, fabricating, installing and operating irradiators, maintaining appropriate nuclear safety conditions, etc.

There may well be other technologies available, but Gray*Star seems to be the only system that is both uniquely American and flexible enough to deal with the Russian food supply without requiring elaborate nuclear safeguards (see attachment). Nevertheless, as currently designed for U.S. applications, Gray*Star also requires considerable volume to achieve irradiated food costs in the cents/pound range. Even so, according to the developer of the Gray*Star irradiator, the Nordion unit has to process 5 to 10 times as much material as Gray*Star to get equivalent costs. Above this `crossover' volume, the larger, higher energy, ^{60}Cobalt reactor is more efficient.

4.5 Critical Cost Factors

While many reports (see Bibliography) have been published concerning the cost of irradiating various classes of food, the fact is that only the FOOD TECH plant in Florida has the potential to operate at commercial scale. All other cost projections available in the U.S. are derived by extrapolating from small scale, so-called “research reactors” and there is therefore some uncertainty concerning irradiation cost other than for very large, bulk-processing of grains. In some countries, government agencies provide an irradiation service, viewing the costs to the economy as being offset by reduction of losses that would have been caused by infestation spoilage and contamination[16]. However, in the case of a commercial irradiation service, the society as a whole does not pay for the irradiation -- consumers and institutions must be willing to bear the extra cost in return for higher quality, healthier food. Food exporters may be able to justify the

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D.W. Thayer is one of the most widely published scientists working in the field of food irradiation. He is at the Eastern Regional Research Center, USDA.

According to estimates of the US Food and Drug Administration (FDA) Division of Microbiology, food-borne diseases cause an economic loss in the U.S. of between $5-17 billion as a result of medical expenses and loss of productivity on the job cost by upgrading products -- which would otherwise not be saleable -- to world market standards.[17]

Of particular interest to this project is the harvesting, further processing, packaging, irradiation, storage and distribution of table foods (as distinguished from grain processing). Generally speaking, the Nordion ^{60}Cobalt reactor requires a fixed investment of close to $5 million and annual operating expense approaching $1 million. The plant, therefore, has to process (depending on the product) one to three million pounds daily to achieve irradiation costs in the $0.05/lb range (approximately $100 per ton). According to Dr. Hargraves of FOOD TECH, their Nordion ^{60}Cobalt irradiation system, running 12 months a year, two shifts a day, irradiates produce and fruit in the $0.03 - $0.05/lb range and meat and poultry in the $0.05-$0.08/lb range. Sterilization of spices costs about $0.10/lb. Comparative data on food irradiation costs on the Nordion and Gray*Star reactors will be found in Appendix C.

As can be seen, even accepting Gray*Star's comparisons without further analysis, the Gray*Star system requires considerable volume to get to a low irradiation cost per pound. Note, however, at low volumes Gray*Star irradiative cost is roughly 15-20% of the ^{60}Cobalt system. This raises two issues:

- Can enough volume of quality food or new or waste biomedical materials be found, suitably packaged for delivery to a Russian irradiation site?

- Will extra cost from lower product volumes create an insuperable cost barrier? That is, if one only can find 7,050,000 lbs of potatoes to irradiate, can the product still accommodate roughly 3.8 cents/lb more + some idle charges? (The potential for using the demonstration unit to sterilize biomedical supplies, thus increasing throughput, will be examined in the next phase of the project.) On the other hand, a MATEK-NFS-Babcock & Wilcox team could well redesign the Gray*Star unit to maximize skilled Russian technicians, increasing ^{137}Cesium reprocessing and usage, creating a somewhat smaller unit. The whole question of utilizing Russian technology and manufacture will have to be examined in some detail in order to project more precise Russian irradiation costs.

4.6 Conclusions and Recommendations

Feasibility of the Project. Based on findings in the preceding sections of this report, we see no major impediments to the establishment of a commercial demonstration food irradiation plant in Russia. Furthermore, we believe that as recognition of the importance of food quality increases in Russia, so too will the likelihood of food irradiation becoming generally employed.

Integration into the Russian Food System. We conclude that only a Russian poultry, meat, or fish processing plant, operating year-round, would have sufficient volume to come even close to cost-

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Inasmuch as fumigants are being phased out globally, this will be an important use of irradiation in some countries, mostly tropical fruit and vegetable producers.

effective irradiation. If there is no Russian entity capable of processing and distributing the product in a cost-effective manner, we believe that a Western processing partner should be sought in order to assure appropriate raw material and quality processing specifications, storage, and distribution -- if not for Russian markets, then for Europe, Japan, and the U.S. In this case, it will be necessary to reach an understanding with the Western firm that some time would be saved for irradiation of other products.

Selection of Irradiator Type. Our preliminary recommendation is to use a ^{137}Cesium irradiating module because (1) it is cheaper to build and to operate (no need for continual recalibration and evaluation), meaning that the relatively low volumes of products which may be available will not have to carry as large a cost burden, and (2) it will utilize ^{137}Cesium, which is available in Russia from re-processed reactor fuel.

Irradiation Safety. Rigorous test procedures will need to be developed to insure the safety of those involved in plant operations, as required by the IAEA and Russian regulatory authorities.

Food Quality and Safety. Tests will be needed to assure the microbiological safety of food emerging from processing plants utilizing irradiation. Records must be maintained to satisfy Russian authorities and/or point of entry requirements of non-Russian countries receiving irradiated products. Adherence to food quality standards will be particularly necessary for products exported to the U.S., Japan or Western Europe. Grades and standards used by those countries must be established and validated by some mutually satisfactory procedure.

Impact on the Russian Food System. It is rigid adherence to quality and safety standards of irradiated food which has the greatest potential to make improvements in the Russian food system. Irradiation will reduce the amount of spoilage when food is sent to market via the somewhat uncertain Russian transportation system. However, the irradiation facility must establish and adhere to a policy of refusing to pay for raw material not meeting agreed quality levels if it is to become a driving force in upgrading the Russian food supply system.

5. PREPARATION OF THE IMPLEMENTATION PLAN

5.1 Introduction

Based on our recommendations in the foregoing section, it is anticipated that the project will move to the second phase -- the preparation of an implementation plan for a demonstration food irradiation facility somewhere in Russia. It is assumed that AMIS II and Nuclear Fuel Services (NFS) will submit a proposal to AID in the near future for funding to carry out this work. The purpose of this section of the report, then, is to lay out an approach to preparing the implementation plan and show how AMIS will contribute to that effort and how tasks to be carried out by the AMIS team relate to those for which NFS/MATEK will be responsible.

The nuclear part of the program will be managed by experienced nuclear specialists to be employed by **MATEK**[18]. This entity was established to "effectively and profitably use the production and scientific-research expertise, commercial and management experience of the Parties in order to contribute to converting high enriched uranium ("HEU") obtained from nuclear weapons into low enriched uranium ("LEU")...as a fuel for nuclear power reactors..." Another portion of MATEK's activities will fund nuclear-site remediation and related environmental activities in Russia, not involving this project.

The implementation plan will establish the justification for the demonstration facility by showing how it would be used, what it will cost to install and operate, who would operate it, where it would be located, and how and where the irradiated products would be marketed. To answer these questions, it will be necessary to identify potential U.S. food company participants, demonstrate that there are no overwhelming problems in marketing the irradiated products domestically or internationally, select an irradiation source and configuration which meet the requirements of the processor, and establish installation and operating costs.

5.2 Definition of Tasks in Preparing the Implementation Plan

Figure 5.1 presents graphically our concept of the two main steps and five tasks involved and how they interrelate. AMIS responsibilities are those which relate to the *applications and specifications* for the irradiation facility -- basically recommending a way to tie the irradiation facility into a food systems operation in Russia -- while those of NFS/MATEK have to do with the *design, fabrication, installation, and operation* of the unit. We visualize the AMIS work as taking place in three phases, as described below, and carried out by a team which includes specialists in agricultural marketing, food processing and irradiation technology.

MATEK is a venture (a Closed Joint Stock Company) comprising the following entities: Ural Electrochemical Plant, Siberian Chemical Plant, Techsnabexport, Priargunski Mining-Chemical Plant, Russian Academy of Science, the Foreign Trade Company "Litintern, and Allied Fuel Energy Services Co.

Figure 5.1

Step I: Basic Studies

Three basic studies need to be carried out in the first phase to lay the groundwork for what follows. They are basically independent of each other and can be carried out in parallel.

Task 1: Identification of Potential U.S. Company Participants and Markets:
This task will determine, as a first priority, who the potential U.S. food company users of the proposed irradiation facility would be, the food products to be irradiated, and the plant locations in Russia. The primary focus will be on U.S. food companies now operating in Russia, especially those which have received grants under the Food Systems Restructuring Program being carried out for AID by Citizens Network. Initial contact has already been made with four of these firms, three of whom have expressed conditional interest in participating. The output of this task will be descriptions of several alternative participating companies, volumes and types of food products to be irradiated, marketing channels, plant locations, and the nature and extent of the company's interest in irradiation. The key will be to identify a marketable product with the highest possible throughput and product value, one where the potential savings in reduced product losses, improved food safety, extended shelf life will justify the cost of irradiation. The potential for compensating for the lack of a reliable "cold chain" for food distribution in Russia by using irradiated food will also be examined. It will also be important to note through which market channels the different companies' products now move or will move, and the extent to which export markets could be exploited. The latter task will require making contacts in markets which currently accept irradiated food, such as South Africa, to determine what regulations might apply to import of such items.

As a second priority, contacts will be made with U.S. pharmaceutical and medical supply firms which may plan to set up operations in Russia. The availability of a sanitary, well-managed facility able to sterilize medical supplies might prove to be an inducement to locate in Russia, and would provide additional justification for the facility. This assumption will be tested by contacting U.S. firms such as Johnson and Johnson.

Task 2: Identification of Potential Russian Applications and Markets.
If the demonstration irradiator is to accomplish its purpose of establishing costs and benefits of irradiation in Russia to guide future development of the industry, at least a portion of the output of iradiated food or sterilized non-food products should be marketed in Russia. Since the objective would be to achieve essentially year-round operation, products available for irradiation in Russia throughout the year would be sought. Some candidate products are: dried egg powder for the Russian military, fresh and frozen fish processed in the Russian Far East for export to Pacific Rim countries, meat and poultry for sale to a "captive market" in Russian "nuclear establishment cities". With respect to biomedical applications, medical facilities and their suppliers (most likely in the Moscow area) would be surveyed by Russian members of the team to determine to what extent irradiators are now used for this purpose, current costs of sterilization by this and by conventional methods, and the level of demand in a typical hospital or hospitals which would be found in a Russian city regardless of location.

Task 3: Marketability of Irradiated Food Products in Russia
The long-term feasibility of a network of food irradiation facilities in Russia will depend on the acceptability of irradiated food to consumers in different parts of the country. Should the demonstration facility rely totally on exports in case the domestic market is effectively closed to irradiated food? If irradiated food products are to be marketed in Russia, which foods (meat, poultry, fish, vegetables, fruit) are most likely to be accepted and in what regions of the country should they be marketed? (There is evidence that consumer attitude toward irradiation in the Russian Far East is much more favorable than in European Russia, with its still vivid memories of the Chernobyl disaster.) It is anticipated that this effort will involve some combination of personal interviews with shoppers and focus group discussions following procedures developed by a specialized group within Abt Associates. The work will be carried out by Russians following procedures developed jointly by AMIS II and the Russian team members. Another element in this task will be the gathering of information on existing (largely undocumented) irradiators in Russia, what products are irradiated, where they are located, whether any of the products are labeled as irradiated, and the extent of consumer knowledge of irradiated foods already being marketed. This work will be carried out exclusively by our Russian colleagues.

Step 2: Definition of the System

Task 1: Determine General Parameters of the Demonstration Facility
The findings from the field work in Phase 1 on potential food and medical products to be irradiated, and on marketability of these products, will be utilized in preparing AMIS findings on the desired general parameters of the demonstration unit -- where it should be located, what food products will be treated in what volumes, the radiation source material, required dosage rates, and in what markets the products will be sold. These findings may be presented in the form of several alternatives. The AMIS report would be translated into Russian by NFS and reviewed by NFS/MATEK prior to the consultation described in Task #2.

Task 2: Determination of System Configuration, Application and Cost This important step in plan preparation would be carried out jointly by AMIS and NFS/MATEK. Findings from Task #1 would be reviewed at a meeting to be held in Russia, including alternative applications for the demonstration unit, as for example, operation by a foreign-owned food company in Russia, or by an entirely Russian owned and managed operation. Alternative arrangements for manufacture of the irradiator also need to be discussed, such as whether the demonstration unit would be: (1) of Russian design and manufacture, (2) manufactured in Russia under license from an American company, or (3) fabricated in the U.S. and delivered to the site in Russia. The outcome of the consultation could be selection of a preferred application and design, or possibly several alternatives. It would be desirable to reach a preliminary agreement at this point with a U.S. or Russian plant operator where the irradiator would be located so that they could participate in this process. A document will be produced jointly by AMIS II and NFS/MATEK at the conclusion of this task describing the unit and how it will be operated, and giving estimated installation and operating costs. A section of the report should deal with the economic justification for the demonstration unit, demonstrating at least provisionally that irradiation costs can be covered by reduced spoilage, longer shelf life, lower transport costs through reduced need for refrigerated vehicles, and/or higher sale prices for products of improved quality and safety.

5.3 Implementation Phase

The project document referred to in Step 2, Task 2 above will serve as the basis for what is referred to in Figure 5.1 as "proposed implementation phase", essentially fixing technical and operating specifications for the demonstration irradiator and preparing detailed estimates of the cost of building and installing the irradiator to fit the specific application agreed upon, as well as the cost of operating it in an industrial environment. These steps may be thought of as the first part of project implementation, culminating in the actual fabrication, installation, and start-up of the unit.

Primary responsibility for implementation will be NFS/MATEK's. The AMIS II role in this phase of the work will be defined during preparation of the next phase proposal. Some possible tasks include: providing the linkages to one or more U.S. food companies during project implementation, establishing irradiator performance requirements based on the selected application, developing operating procedures in enough detail to permit NFS/MATEK to calculate personnel and other operating costs, drafting proposed food safety standards and food quality standards for the unit (since these too will have an impact on operating costs), and drawing up procedures for initial testing of the unit.

Once costs are established, specifications concerning the radiation source material and configuration of the irradiator can be formulated in sufficient detail to permit the irradiation system supplier/fabricator to prepare a detailed cost proposal to NFS/MATEK. The final part of this phase will be the preparation of a business plan by NFS/MATEK for the use of prospective investors in a company to build and operate future irradiation facilities in Russia.

The overriding objective of the demonstration will be to operate the unit in such a way that the information collected will enable MATEK to decide on the feasibility of establishing irradiators throughout Russia and the NIS for food and medical applications.

6. PROPOSED WORK PLAN, STAFFING AND COSTS

The activities described in the preceding Section 5 of this report will be carried out in close cooperation with NFS/MATEK through a management team consisting of participating American and Russian organizations. It is anticipated that all AMIS tasks, with the exception of Step I, Task #1 (Identification of Potential U.S. Company Participants and Markets), will be carried out jointly with Russian agribusiness representatives under the direction of the AMIS team.

AMIS II proposes a three-person team to carry out the work. The three individuals proposed for the team are identified at the end of this section. The time allocated for each person is shown by task in the following work plan, which is keyed to the task description in Section 5 of this report.

Step I - Basic Studies

***Task #1:* Identify Potential U.S. Company Applications**

Identify U.S. agribusiness firms with potential interest in participating in project at existing or planned processing plants in Russia, and ascertain types and volumes of food products which would be irradiated. Determine through personal contact (via phone, e-mail or fax) potential acceptability in selected foreign markets of the identified products, and what regulations may apply to their sale. Determine potential demand for sterilization of biomedical supplies and materials by U.S. companies who are established or who may establish operations in Russia. Work to be carried out entirely in the U.S.

Project Director: 10 days
Int'l Food Mktng Spec: 8 days
Irrad Food Qual Spec: 8 days

Task #2: Identify Potential Russian Applications and Markets

Identify potential users of demonstration irradiation facility in Russia, locations and products, including both food and biomedical supplies. After consultation with the AMIS team, Russians assigned to the project will carry out initial investigations in Russia and will prepare a report in English for AMIS. Following review of the report, the AMIS three-person team will go to Russia for two weeks to visit the most promising sites previously identified and meet responsible officials. Upon return, the AMIS team will prepare a brief report with conclusions as to the feasibility of one or more of the proposed sites and applications.

Project Director: 20 days
Int'l Food Mktng Spec: 20 days
Irrad Food Quality Spec: 20 days
Russian team members: approx. 30 person-days

Task #3: Marketability of First Irradiated Products in Russia

Determine marketability of irradiated food products in Russia by means of informal surveys and focus groups, and establish whether there are any regional differences in consumer acceptance. Determine what irradiated foods are now being marketed, where and through what channels, and whether they are

labeled as such. This task to be carried out by Russian members of the AMIS/MATEK joint team by means of meetings and informal surveys in various regions in Russia, and a report on findings presented in English to AMIS. The work would be launched after consultation with the AMIS team during the trip under Task #2.
Project Director: 1 day
Int'l Food Mktng Spec.: 2 days
Irradiation Food Quality Spec.: 2 days
Russian team members: approx. 50 person-days

Step II - Definition of the System

Task #1: Determine General Parameters of Demonstration Irradiator
Prepare alternative recommendations on the general parameters of the irradiator to meet the needs of the potential users identified in Step I. For each alternative, determine the technical features of the irradiation unit, such as on-line or off-line configuration, methods of handling material into and out of the irradiator, irradiation source, throughput, etc. Recommendations should include the possibility of U.S. sourcing of the irradiator, together with information on design, delivery time, and estimated costs. Report to be submitted in English and translated into Russian by NFS/MATEK. Based on the parameters defined in the AMIS report, NFS/MATEK should at this point begin preparing comparative cost estimates for a Russian-designed and built irradiator.
Project Director: 13 days
Int'l Food Mktng Spec.: 7 days
Irrad Food Quality Spec.: 7 days

Task #2: Determination of System Configuration, Application, and Cost
It is expected that AMIS findings on the parameters of the demonstration unit as defined in Task #1 above would be discussed at a joint AMIS- NFS/MATEK meeting in Russia. This will require a second one-week trip to Russia by all three AMIS team members. At the same time, information generated by NFS/MATEK as to the possibility of Russian fabrication of the irradiator, and associated cost estimates, will be reviewed. The outcome of these meetings should be decisions on the preferred application of the irradiator and how and where it would be fabricated and at what cost. Activities under the next phase of the project will also be planned.
Proj Director - 8 days
Int'l Food Mktng Spec - 8 days
Irrad Food Quality Spec. - 8 days

Summary: Proposed Staffing and Time Allocations

Project Director:	Dr. Richard S. Gordon	50 days
International Food Marketing Spec.:	Richard D. Abbott	45 days
Irradiation Food Quality Spec.:	William P. Hargraves	45 days

Estimated Costs:
Cost of the time of the above three individuals, their travel to Russia and within the United States, and all other associated costs is $181,000. We do not have sufficient information to estimate the costs of the time and travel for the estimated 80 person-days of time of the Russians who would work with the AMIS team, but an allocation of $19,000 for this purpose would bring total costs to $200,000.

It should be noted that these costs do not include AMIS II tasks under the implementation phase described in section 5.3 above.

APPENDIX B
CONSUMER ACCEPTANCE SURVEY RESULTS

1. Summary of UN Consumer Survey

A recent document prepared for the UN Environment Program summarized the results of 37 consumer surveys conducted in 12 countries, including 22 in the U.S. alone, since 1984[19]. While results are often conflicting, a summary of reponses to key questions in the U.S. surveys is roughly as follows:

Do you consider irradiation, pesticide and herbicide residues, chemical preservatives and antibiotic and hormone residues to be health hazards? Most respondents said they considered these to be health hazards, but felt more strongly about the risks from pesticides and herbicides than from radiation.

Would you purchase and serve irradiated foods to your family? Several surveys asked questions of this nature and found that among people who had heard of irradiation and had opinions, about half the respondents said they were likely to purchase these foods. Of the half who would not, most felt that the foods were dangerous but needed more information to be sure.

Would labeling food as irradiated make any difference to your attitude? Consumers generally felt that irradiated food should be labeled as such , but there was no clear indication that this meant that they would tend to buy more of the labeled food. Those who considered irradiated food a health hazard said that labeling would make no difference.

Would you pay more to obtain the benefits of irradiated foods? When asked the general question in one survey, more said they would not then those who said they would. When asked about specific foods in other surveys the reaction was different: 60% to 80% said they would pay more for a reduction of bacteria in chicken or beef, a reduced risk of trichinosis infection in pork, or extended shelf life of strawberries, peaches and mushrooms.

2. American Consumer Attitude Toward Irradiation of Meat

The American Meat Institute published in November 1993 the results of an important three-part study of consumer attitudes toward irradiated meat. The study included a nationwide telephone survey by The Gallup Organization, a series of focus groups conducted by Abt Associates, and a grocery store shopping simulation test by the Center for Food Safety and Quality Enhancement at the University of Georgia.

"Commercial Food Irradiation, Market Tests, and Consumer Attitiude Research - Summary Tables", Michelle Marcotte, Prepared for UN Environment Program, Methyl Bromide Technical Options Committee, February 1994.

Concern about food safety and safety of food processing techniques. High levels of concern about food safety were found in both the Gallup survey and the Abt Associates focus groups. The Gallup study found more concern over bacteria-destroying food preservation techniques such as chemical treatments (like chlorination) and irradiation, than about the more familiar pasteurization, canning, fermentation, and freezing processes. The Abt Associates and University of Georgia work indicated greater concern by consumers over the presence of drug residues and hormones in meat than in irradiation.

Knowledge about food irradiation. Gallup found that 73% of respondents had heard of irradiation, half were aware of it but did not know much about it, and only 19% said they knew something about it. Consumers were most concerned about perceived negative health effects of irradiation, such as birth defects, environmental pollution, and reduced level of nutrients and vitamins. After being informed that the process kills bacteria and had been approved by the FDA and the World Health Organization, more than 40% considered irradiation necessary for pork, poultry, and seafood, 36% said it was necessary for beef, and 23% said so for fruits and vegetables.

Purchase intent. When the benefits of irradiation -- bacteria elimination and preservation of freshness -- were explained, about half of the respondents said they would buy irradiated food products. Poultry (52%) was the largest category, followed by beef, pork, fruit and vegetables, and seafood. The shopping store simulation showed that the proportion of shoppers who would buy irradiated beef went up from 52% to 71% after hearing a brief educational message on the benefits of irradiation.

Third party endorsement. Independent endorsement of the safety of irradiation increased consumer confidence. The American Medical Association's endorsement had the greatest impact, followed by the FDA, USDA, and World Health Organization.

3. The Iowa State University Study

The most recent major study on consumer acceptance was carried out by Iowa State University in 1995.[20] Subjects were 80 women and 51 men of between 18 and 77 years of age, with a median family income of $52,500, of which 103 had at least a four-year college degree -- thus a rather special group. About 53% had some prior knowledge of food irradiation. Acceptance of food irradiation was measured by four variables: (1) opinion of food irradiation, (2) perceived health risk, (3) activism (liklihood of actively opposing food irradiation), and (4) taste. Participants were given a three-page paper which presented arguments for and against food irradiation and saw a video which also presented both sides.

An initial questionnaire measured food safety concern by asking about the perceived liklihood of harmful effects from food additives, level of concern about food safety , perceived control over the

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"Social Demographic and Attitudinal Determinants of Consumer Acceptance of Food Irradiation", Sapp, Harrod, and Zhao, in Agribusiness, Vol. 11, No. 2 (1995) risk of eating irradiated food, trust in government and industry, response to the opinion of scientists, and response to views of consumer advocate groups. Afterward, participants exchanged views in small discussion groups before completing a final questionnaire. (The discussion within the groups was designed to duplicate the effect of sharing opinions among consumers.) Finally, participants took part in a blind taste test in which they were asked to detect any perceived differences between irradiated and non-irradiated roast chicken pieces. Results, summarized below, were not always what had been expected.

< Opinion of food irradiation was slightly positive (11 on a scale of 1 to 20) at the outset, and increased only slightly after presentation of information for and against irradiation.

< Group discussion resulted in a convergence of views, i.e. differences were reduced after exchange of views.

< There was little significant effect on responses due to whether respondents had prior knowledge of or concern about irradiation.

< Males had a significantly higher opinion and lower level of perceived health risk and tendency toward activism than females regarding food irradiation.

< Opinions of consumer advocates and trust in government and industry were the key determinants of consumer acceptance.

< Results support the hypothesis that negative information (from consumer advocates) carry disproportionate weight in influencing consumer acceptance.

The study concludes that it will continue to be necessary to provide information to the public on research on the benefits of food irradiation. Publications should "actively challenge the qualifications and motivations of irresponsible advocacy groups", and should "reaffirm the credibility of government and industrial organizations responsible for food irradiation". In the latter connection, educational messages should address not only the findings of research but the rigorous procedures involved in producing and evaluating findings by scientists, regulatory agencies, and irradiation processors.

In connection with the above findings, an interesting result of a 1989 survey by Bord and O'Connor[21] based on focus groups was that individuals were actually more favorable toward irradiation than they thought that other people were. This corresponded to findings from studies of focus groups by the same authors to the effect that negative comments dominated discussion. They speculated that this occurred because some people were hesitant to appear too positive in the face of negative views expressed by others. (Further speculation by one author of this report is that those with negative views are often those who see things in simplistic terms and express their views very strongly, making others with less strongly held views hesitant to disagree.)

4. Consumer Surveys Outside the United States

The document prepared for the UN Environment Program in 1994 (see Footnote #2) includes results of seven consumer surveys carried out in countries outside the U.S. They can be summarized as

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Bord, R. And R.E. Connor, *Who Wants Irradiated Food?: Untangling Complex Public Opinion,*Food Technology, 43, 87, (1989) follows:

Argentina: 90% of those surveyed said they would purchase irradiated food.
Australia: 62% said they would not purchase irradiated food, mostly because of health concerns, though 60% of them said it was because of insufficient knowledge of the process.
Canada: In a 1988 survey, 1/3 said they had a favorable opinion of irradiation and 1/3 had an unfavorable opinion. However, 40% of those who had heard of the process, preferred it over the use of chemical preservatives. Another survey in 1993 found 51% were doubtful about the safety of irradiated foods, 26% unsure, and 23% confident in its safety.
China: In 1991, 72% of those surveyed were willing to buy irradiated foods. Among those with misgivings about these foods, a high proportion said that their doubts were removed after seeing information about the process.
Korea: 37% would buy irradiated foods, while 51% needed more information before deciding.
Mexico: After receiving information on the process, 62% said they would eat irradiated foods, 17% said they would not eat it, and 20% were unsure.
Netherlands: A 1988 survey found 56% against irradiation and 34% neutral on the subject. In a 1992 survey, 39% had positive comments, and 29% were negative. When asked if they would buy irradiated food, 1/3 said they would and another 1/3 said they would not.

The above surveys dealt with attitudes toward irradiated foods in general and found, on balance, that the majority still had negative feelings about irradiation.. It is interesting to note, however, that attitudes toward irradiation of certain types of food were considerably more positive. For example, 90% of respondents in a Polish survey would purchase irradiated potatoes. In China, a similar 90% would buy irradiated apples. This was true also in U.S. surveys, where 80% of respondents in one survey would buy irradiated papaya and 54% would prefer irradiated to fumigated tropical fruit.

APPENDIX C
COMPARATIVE COSTS OF GREY STAR AND NORDION IRRADIATORS

Table 4.1
Gray*Star Costs (^{137}Cesium) vs. Nordion (^{60}Cobalt) Irradiators

	^{137}Cesium		^{60}Cobalt	
Product	lbs/yr	cents/lb	crossover*lbs	days/year
Poultry	23,300,000	1.28	154,000,000	350
Potatoes	70,500,000	0.38	443,000,000	130
Papayas	50,000,000	0.49	333,000,000	270
Mangoes	36,900,000	0.54	326,000,000	150
Cherries	11,700,000	1.67	107,000,000	60
Onions	49,200,000	0.47	337,000,000	84

*Crossover pounds = the amount required to be irradiated by Nordion ^{60}Cobalt irradiator to get the same cost/lb as from Grey*Star system (from cost calculations developed by Gray*Star).

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